

FLEXURAL BEHAVIOUR OF RCC BEAM WITH PARTIALLY REPLACED CONCRETE BELOW NEUTRAL AXIS

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Abstract - This study focuses on optimization of concrete used in tension zone by partial replacement with either low grade concrete, or hollow section or both, and to investigate the cracking and flexural behavior of the same. For this experiment six group of beam have been casted. First three groups comprise of M-25 concrete, above neutral axis (N.A) and lower grade concrete below N.A. zone, and remaining three group is same as first three group except that zone below N.A. is also partially replaced with a hollow void in longitudinal direction. Flexural behavior has been studied for the above cases. Control beam is of M-25 grade and low grade concrete used are of M-20 and M-15 grade. Hollow UPVC pipe (diameter=63mm/2.5") were used to replace concrete and to create hollow void throughout the length of concrete. Dimension of beam specimen is 150x150x700 mm and flexural test has been carried out with three-point loading using Universal Testing Machine. From experiment it is found that in heterogeneous solid beams with lower grade concrete below N.A. reduction in ultimate load is about 15% to 25% whereas for hollow beams reduction is about 25% to 40%. In case of solid heterogeneous beams deflection increases by 80% to 100%.

Key Words: neutral axis, flexural capacity, hollow core, heterogeneous, RCC beam.

1. INTRODUCTION

A beam is a two dimensional structural member which resist transverse loading by means of bending or flexural stresses. Concrete is most widely used material in any structure because of its ease in production, casting and strength. But concrete is weak in tension. To overcome this weakness, concrete is generally reinforced with steel, known as reinforced concrete. When a beam is loaded there are two zones is to be considered i.e. tension zone and compression zone. Since concrete is quite weak in tension (having tensile strength 1/10 of its compressive strength generally), in general design of RCC beam, it is assumed that all compressive stress is taken by concrete in compression zone above the neutral axis and all tensile stresses are taken by steel only. Concrete in tension zone only act as a strain transferring media between concrete in compression zone and tensile reinforcement, by means of bond in between steel bars and concrete. Various experimental and numerical works are carried out for the investigation of alternate materials that can be used to replace concrete in tension

zone, materials such as fly ash, slag, rice husk, lightweight aggregate etc. In previous studies it is found that replacing the concrete below the neutral axis with inert light weight material such as hollow PVC pipes, polyethylene balls, polystyrene foam etc. will not greatly affect the strength, stress geometry and shape characteristics of the beam. Previous studies on partial replacement of concrete below the neutral axis in beams by creating air voids using different size of polyethylene balls and PVC pipes has been carried out which has been studied. Providing hollow section often adopted for lightweight beam structure and highly elevated bridge piers in order to reduce its weight. The concept is similar as hollow slab panels, widely adopted in bridge and highway construction. Referring to the second moment of inertia law, the reduction of the cross sectional area of the beam will reduce section modulus which in turn affects the bending moment and shear resistance of the beam. Therefore, an experimental investigation is necessary in order to evaluate performance and feasibility of such beams with hollow cross-section.

1.1 Objectives of Study

The main objective of this experimental investigation is as follows:

- To study flexural behavior of heterogeneous beam having partially replaced low grade concrete (in tension zone) in contrast to solid conventional RCC beam.
- To study the flexural behavior of RCC beam with partially replaced low grade concrete and hollow section in tension zone.
- To analyze and compare the cracking pattern and mode of failure in above cases.

1.2 Scope of Work

This experimental study is focused on assessment of flexural behavior of RCC beam with low grade concrete below the neutral axis and simultaneously with low grade concrete plus hollow void below N.A. of the beam. Six different groups of beams (3-specimen for each group) including control beam of M-25 grade with dimension of 150mm height, 150mm width and 700mm length have been casted.

- Group-1 consists of conventional solid RCC beams of M-25 grade.(Designated as **BM25**)
- Group -2 consists of solid beams with M-25 concrete on compression zone and M-20 grade concrete in tension zone.(Designated as **BM25+20**)
- Group -3 consists of solid beams with M-25 concrete on compression zone and M-15 grade concrete in tension zone. (Designated as **BM25+15**)
- Group -4 consists of beams same as control beam with M-25 concrete except that tension area is replaced partially with hollow UPVC pipe of 63 mm diameter. (Designated as **BM25H**).
- Group -5 consist of beams with M-25 grade concrete on compression zone and low grade M-20 concrete in tension zone is partially replaced with hollow void with help of UPVC pipe of 63 mm diameter approximately reducing cross section al area by 26%.(Designated as **BM25+20H**)
- Group -6 consist of beam with M-25 concrete in comparison zone and M-15 concrete partially replaced with hollow UPVC pipe in tension zone.(Designated as **BM25+15H**)

For main reinforcement and shear reinforcement steel bar of size 10mm and 8mm have been used respectively. The main reinforcement Fe-500 grade deformed bars and for shear link reinforcement Fe-250 grade have been used. The beam specimens were tested for the flexural strength, to determine which one of the beam will have more flexural strength. All beam specimens were compared in term of deflection and mode of failure. Experimental testing involve 3-point test (flexural test) with Universal Testing Machine (1000 KN) to record the load and deflection values.

2. MATERIALS AND MIX-DESIGN

Cement-All through the experimental study, Ordinary Portland Cement of 53 Grade conforming to IS: 269:2015 was used, which comprises good quality. Physical and chemical properties are in acceptable limit.

Aggregate- Sand as fine aggregates with maximum size 4.75 mm are collected as per availability and sieved to make it confirm to zone-II, as per IS: 383-1970. Sieve analysis is done to determine fineness modulus and test were conducted to determine specific gravity and bulk modulus. Locally available coarse aggregate of maximum size 20 mm is used. Specific gravity, bulk density of aggregate is determined as well as grading analysis is done to determine the particle size distribution. Physical properties of aggregates were evaluated as per IS: 2386 (Part III)-1963 as shown in table-1.

UPVC pipe: A SWR UPVC pipe has been used to replace the concrete and to create hollow longitudinal void in beam. Pipe

used is of 63 mm (2.5”) in diameter and of wall thickness 1.5 mm. UPVC pipe is regular PVC without addition of plasticizers, which makes it rigid than PVC pipes.

Steel reinforcement-Hot rolled deformed bars of Fe-500 grade conforming IS 432:1982 have been used. Strength and ductility requirement of steel rebar is as per the limits specified in IS 1786:2008. Rib pattern bars are of diameter 8mm, 10 mm is used

Table -1: Properties of Aggregates

Physical properties	Coarse aggregate	Fine aggregate
Specific gravity	2.77	2.65
Bulk density(kg/m3)	1540	1770
Water absorption	Nil	Nil
Fineness modulus	6.72	2.81
Maximum size	20mm	2.36 mm

2.1 mix-proportion of concrete

Table 2.1: final mix proportion for M-25 grade

water	cement	Fine aggregate	Coarse aggregate
197	448	637.74	1141.6
0.44	1	1.42	2.54

Table 2.2: final mix proportion for M-25 grade

water	cement	Fine aggregate	Coarse aggregate
197.16	394.32	654.14	1171.33
0.5	1	1.65	2.97

Table 2.3: final mix proportion for M-25 grade

Water	Cement	Fine aggregate	Coarse aggregate
197.16	358.18	665.71	1192.07
0.55	1	1.85	3.32

3. EXPERIMENTAL PROGRAM

3.1 Preparation of Specimens

Standard beam mould with internal dimension 700mm x 150mm x 150mm as per the specification of IS 10086:1982

has been used. Well oiling is done before pouring concrete in mould on all internal surface of mould and all nuts are tightened well to avoid any leakage of material during compaction process. Deformed bars (Fe-500) of 2 nos. /10 mm diameter is used as tension reinforcement and 2 no. /8 mm bars are used for both in compression zone and for shear reinforcement. Shear reinforcement is of size 100mmx100 mm @100 mm c/c spacing is provided with all-around nominal cover of 20 mm. After arranging all material of required grade and specification and after testing trial mix design, required quantity of materials is prepared at laboratory by manual weight batching. Concrete mix of required grade is prepared with hand mixing for this work. Proper care is taken to produce a homogeneous mix and maintain consistency for each batch. During casting of heterogeneous beam a time gape of 1hour is maintained to produce required section of beam with different grades and avoid mixing of two grades. After pouring concrete beam is compacted properly by using table vibrator. After 24 hours specimens were removed from the mould carefully. After removal of beams it is immersed in water for next 28 days for proper curing.

contact with beam surface and loading is started. The value of load imposed and displacement value is recorded and saved for later analysis. Cracking pattern is observed during loading and at failure. Cracking pattern and mode of failure is shown in fig-4.



Fig -1: casting of specimen



3.2 Testing of Specimens

After proper curing for 28 days beams were taken out and excess water is wiped off by clothes. Beams are checked for any irregularity. Beams are tested when it is still in wet condition. Beams are tested under 3-point loading (fig-3) with the help of Universal Testing Machine of capacity 1000 KN. Beam is placed properly on roller support at marked positions and loading plunger is adjusted at the center of beam. After checking the whole setup, plunger is brought in



Fig -2: preparation of specimens for testing



Fig -3: Testing of specimens

4. RESULTS AND DISCUSSION

4.1 Results

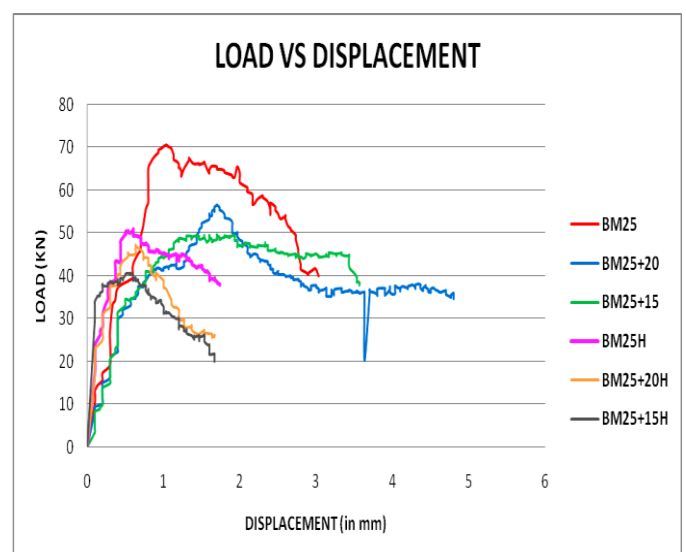


Chart -1: Load vs. Displacement graph of all beam groups

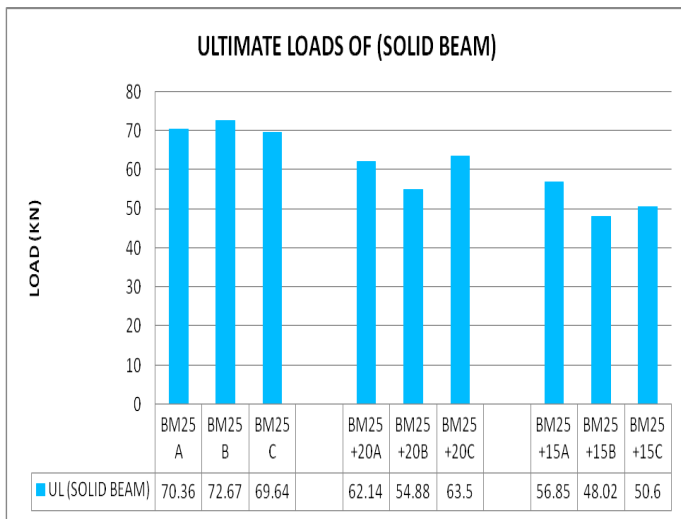


Chart -2: Ultimate Load of solid beams

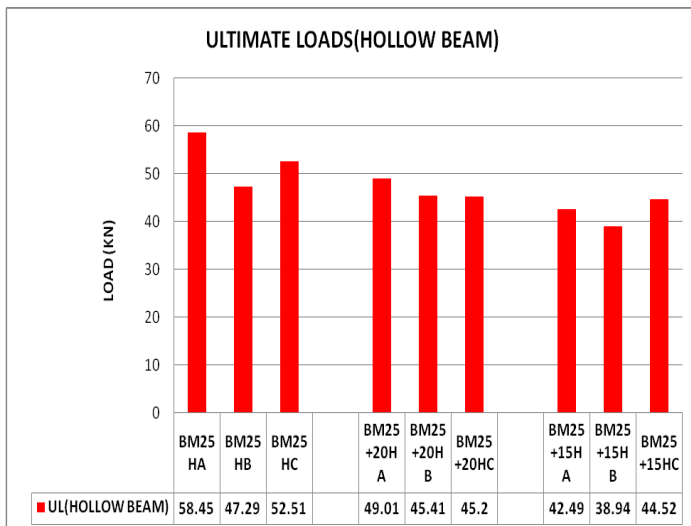


Chart -3: Ultimate Load of hollow beams

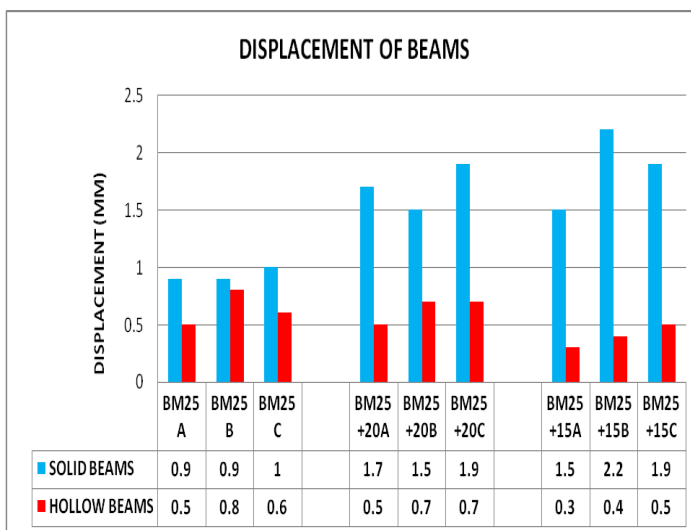


Chart -4: Displacement of beams



(a).Group-1

(b).Group-2



(c).Group-3

(d).Group-4



(e).Group-5

(f).Group-6

Fig-4: Cracking pattern and mode of failure

4.2 Discussion

- By comparing the load versus displacement graph of control beams and solid heterogeneous beams we conclude that, maximum flexural strength of heterogeneous beams are decreases approximately about 15%-25% (chart-1) with increase in grade difference of concrete. While the deformation capacity increases with grade difference ($\Delta_{Group-3} > \Delta_{Group-2} > \Delta_{Group-1}$).in solid heterogeneous beam (Group-2 and Group-3).this is because of formation of diagonal shear cracks in solid heterogeneous beams.
- The cracking pattern of conventional RCC beam has ductile failure in which crack occurs at bottom fibers in mid-span. In heterogeneous beams (Group-2 & Group-3), it has shear failure pattern in which the crack occurs at support first and crack line goes diagonally towards the point of load application region. In hollow beams (Group-4, Group-5 and Group-6) the failure occurs as brittle flexure failure which is due to crushing of concrete at top fiber before yielding of tension reinforcement. This is because of lack of strain transferring media in tension zone (fig: 4).
- In hollow beams Group-4, Group-5 and Group-6 the ultimate load peak has reached abruptly. It can be seen as grade difference increases the peak load will also reach more abruptly. Maximum flexural strength of hollow beams (chart-1) are decreases as compare to that of solid conventional beam (approximately about 25% to 40%).Though, in hollow beam deflection is less (chart-4) and as the grade differences increases the deflection is lesser ($\Delta_{Group-1} > \Delta_{Group-4} > \Delta_{Group-5} > \Delta_{Group-6}$).this is because hollow beams fails at lower load and also hollow UPVC pipe slightly increases moment of inertia of section.
- From the calculation of coast of beams it has been seen that by replacing low grade concrete below N.A. reduction in cost up to 5% and with hollow core reduction in cost up to 8% can be achieved.

Table-3: coast of beams per unit

Beam	Cost of beam per unit (In Rs.)
BM25	195
BM25+20	185
BM25+15	184
BM25H	185
BM25+20H	181
BM25+15H	180

5. CONCLUSIONS

From the analysis of test results obtained and observation of cracking pattern following conclusion are drawn:

1. From bar chart plotted (chart- 2) it is seen that there is not much difference in ultimate load capacity of solid conventional beam, and that of heterogeneous beam with low grade concrete, difference is about (14.95%) for BM25+20 and about (26.92%) for BM25+15.however with increase in grade difference decrease in capacity is significant.
2. For hollow beams it is observed that with provision of hollow section in conventional RCC beam reduction in ultimate load capacity is significant about (25.8%).
3. With decrease in grade of concrete placed below neutral axis of solid beams (BM25+25, BM25+20, BM25+15), there is very significant amount of increase in the deflection of beams and is about (82.7%) in case of BM25+20 and about (99.35%)in case BM25+15 as compare to solid conventional beam with M-25 grade only(chart-4).
4. In case of hollow beams there is not much difference in deflection of conventional solid beam(BM25) and hollow beam with uniform grade of concrete (BM25H).
5. From results it is seen that deflection of hollow beams reduces with increase in grade difference of concrete, in case of hollow heterogeneous beams. by partially replacing low grade concrete with hollow core in tension zone (i.e. BM25+20H, BM25+15H).reduction in deflection is about 32.25% for BM25+20H and 56.9% for BM25+15H as compare to that of solid section, though ultimate load is also reduces.
6. From observation of cracking pattern (fig-4) and load vs. time graph it is seen that as grade difference above and below N.A. increases beam shows shear failure, while brittle flexural failure is observed in hollow beams with minimum deflection.

From experimental it has been observed that the replacement of concrete with lower grade concrete below neutral axis does not significantly affect flexural capacity of beam, also reduces cost and weight of beams. Such beams can be used in precast construction, lightweight and elevated structure, plinth beams, raft foundation etc. In hollow beams some in-filled material can be used to improve strain transfer capacity into tension reinforcement and avoid its brittle failure. Stress-Strain analysis can be done, to get a more clear understanding of behavior of hollow and heterogeneous beams.

REFERENCES

- [1] Vanissorn Vimonsatit^{1*}, Ade S. Wahyuni² and Hamid Nikraz¹, "Reinforced concrete beams with lightweight concrete infill", *Scientific Research and Essays Vol. 7(27)*, pp. 2370-2379, 19 July, 2012.
- [2] Susumu Inoue and Noriaki Egawa, "Flexural and Shear behavior of concrete hollow beams under reversed cyclic load", 11 WCEE, ISBN: 0 08 042822 3.
- [3] Ibrahim G. Shaaban, Yousry B. Shaheen, Essam L. Elsayed, Osama A. Kamal, Peter A. Adwsina, "Flexural characteristics of lightweight ferrow cement beams with various types of core materials and mesh reinforcement", *Construction and Building Materials* 171(2018)802-816.
- [4] Ahmad Jabbar Hussain Alshimmeri, Hadi Nasir Ghadhbhan Al-Maliki "Structural Behavior of Reinforced Concrete Hollow Beams under Partial Uniformly Distributed Load", *Journal of Engineering*, Volume 20 July - 2014.
- [5] Zuhair Faruq Namiq, "Design of beam as a hollow cross section by using steel fiber under pure torsion", University of Salahaddin - Hawler, February-2012.
- [6] Z.J. Yang and Jianfei Chen "Finite element modelling of multiple cohesive discrete crack propagation in reinforced concrete beams", *Engineering Fracture Mechanics* 72 (2005) 2280-2297.
- [7] O. Orie and B. Idolor, "Optimizing compression zone of flanged hollow core concrete beam using moment of inertia theory", (NIJOTECH) Vol. 34 No. 2, April 2015, pp. 217 - 222.
- [8] H S Lim¹, T H Wee¹, M A Mansur² and K H Kong, "Flexural behavior of lightweight aggregate concrete", (APSEC 2006), 5 - 6 September 2006.
- [9] Amr A. Gamal "Strengthening Techniques in Reinforced Concrete Hollow Core", (IJEIT) Volume 4, Issue 8, February 2015.
- [10] Ali Said Alnuaimi, Khalifa S. Al-Jabri, Abdelwahid Hago, "Comparison between solid and hollow reinforced concrete beams", *Materials and Structures* (2008) 41:269-286.
- [11] M.A. Mansur, "Design of reinforced concrete beam with web opening", (APSEC 2006), 5 - 6 September 2006.
- [12] P Sivaneshan and S Harishankar, "Experimental Study on Voided Reinforced Concrete Beams with Polythene Balls", *IOP Conf. Series: Earth and Environmental Science* 80 (2017) 012031.
- [13] Anju Varghese, Basil.M.Joseph, "Experimental and Numerical Studies on Reinforced Concrete Hollowcore Sandwich Beams", *IJRSET*, Vol. 5, Issue 8, August 2016.
- [14] Jain Joy and Rajesh Rajeev, "Effect of Reinforced Concrete Beam with Hollow Neutral Axis", *IJSRD*, Vol. 2, Issue 10, 2014.
- [15] N parthiban¹, Dr M Neelamegam², "Flexural behavior of reinforced concrete beam with hollow core in shear section", (IRJET), Volume: 04, Issue: 04, Apr -2017, p-ISSN: 2395-0072.
- [16] Mita Ann Zachariah, Sunitha A Daniel, "Experimental Analysis of Flexural Behavior and Crack Pattern of RCC Composite Beam", *IJSTE*, Volume 3, Issue 03, September 2016.